इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

"जानने का अधिकार, जीने का अधिकार"
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS 3842-6 (1972): Application Guide for Electrical Relays for ac Systems, Part 6: Power Relays [ETD 35: Power Systems Relays]

"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

BLANK PAGE

BRUTUM FULMEN
IGNORANTIA JURIS NON EXCUSAT
PROTECTED BY COPYRIGHT

IS : 3842 (Part VI) - 1972

(Reaffirmed 2001)

Indian Standard

APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR ac SYSTEMS

PART VI POWER RELAYS

(Third Reprint OCTOBER 1985)

UDC 621·316·925

© *Copyright* 1972

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5

August 1972

Indian Standard
APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR ac SYSTEMS
PART VI POWER RELAYS

Relays Sectional Committee, ETDC 35

Chairman	*Representing*
SHRI K. M. CHINNAPPA	Tata Hydro-Electric Power Supply Co Ltd, Bombay
Members	
SHRI G. K. THAKUR (*Alternate* to Shri K. M. Chinnappa)	
SHRI N. S. S. AROKIASWAMY	Tamil Nadu Electricity Board, Madras
SHRI T. B. CHIKKOBA (*Alternate*)	
SHRI M. M. BENDRE	Maharashtra State Electricity Board, Bombay
SHRI Y. N. BHARGAVA	Universal Electric Co, 24 Parganas
SHRI G. R. BHATIA	Directorate General of Supplies & Disposals (Inspection Wing)
SHRI S. R. K. MURTHY (*Alternate*)	
SHRI A. DATTA	Jyoti Limited, Baroda
SHRI B. L. SINHVAL (*Alternate*)	
DEPUTY DIRECTOR STANDARDS (SS/TI), RDSO, LUCKNOW	Railway Board, New Delhi
ASSTT DIRECTOR STANDARDS (RELAYS) (*Alternate*)	
DIRECTOR, CENTRAL POWER RESEARCH INSTITUTE, BANGALORE	Central Water & Power Commission (Power Wing), New Delhi
DEPUTY DIRECTOR, CENTRAL POWER RESEARCH INSTITUTE (*Alternate*)	
SHRI P. S. ENDLAW	Directorate General of Posts & Telegraphs, New Delhi
SHRI S. GOVINDAPPA	Mysore State Electricity Board, Bangalore
SHRI D. P. GUPTA	Directorate General of Technical Development, New Delhi
SHRI S. PALHAN (*Alternate*)	
SHRI P. A. KRISHNASWAMY	U.P. State Electricity Board, Lucknow
SHRI A. D. LIMAYE	Bombay Electric Supply & Transport Undertaking, Bombay
SHRI A. M. KELKAR (*Alternate*)	
SHRI MOHINDER PAL	Haryana State Electricity Board, Chandigarh
SHRI K. L. MIGLANI (*Alternate*)	
SHRI S. K. MUKHERJEE	National Test House, Calcutta
SHRI S. T. PATEL	ASEA Electric India Pvt Ltd, Bombay
SHRI M. P. MOBEDJINA (*Alternate*)	

(*Continued on page* 2)

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

(*Continued from page* 1)

Members	*Representing*
SHRI M. S. RAJAGOPALAN	English Electric Co of India Ltd, Madras
SHRI N. NATH (*Alternate*)	
SHRI A. RAJA RAO	Heavy Electricals (India) Ltd, Bhopal
DR T. S. M. RAO	Roorkee University, Roorkee
SHRI U. V. RAO	Hindustan Brown Boveri Ltd, Bombay
SHRI V. BALASUBRAMANIAN (*Alternate*)	
SHRI P. RENGASWAMY	Hindustan Steel Ltd, Ranchi
SHRI T. C. RAJAGOPALAN (*Alternate*)	
SHRI R. K. SHARMA	International General Electric Co of India Pvt Ltd, Bombay
SHRI M. M. SHETHNA	Siemens India Ltd, Bombay
SHRI S. V. AJREKAR (*Alternate*)	
SHRI Y. S. VENKATESWARAN, Director (Elec tech)	Director General, ISI (*Ex-officio Member*)

Secretary

SHRI VIJAI

Assistant Director (Elec tech), ISI

Panel for Application Guide for Electrical Relays, ETDC 35 : P 2

Convener	
SHRI G. K. THAKUR	Tata Hydro-Electric Power Supply Co Ltd, Bombay
Members	
DEPUTY DIRECTOR, CENTRAL POWER RESEARCH INSTITUTE, BANGALORE	Central Water & Power Commission (Power Wing), New Delhi
SHRI M. P. MOBEDJINA	ASEA Electric India Pvt Ltd, Bombay
SHRI N. NATH	English Electric Co of India Ltd, Madras
SHRI V. RADHAKRISHNAN	Heavy Electricals (India) Ltd, Bhopal
SHRI P. K. SEN	Punjab State Electricity Board, Patiala
SHRI M. M. SHETHNA	Siemens India Ltd, Bombay

Indian Standard
APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR ac SYSTEMS
PART VI POWER RELAYS

0. FOREWORD

0.1 This Indian Standard (Part VI) was adopted by the Indian Standards Institution on 17 April 1972, after the draft finalized by the Relays Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 Modern power systems are designed to provide uninterrupted electrical supply, yet the possibility of failure cannot be ruled out. The protective relays stand watch and in the event of failures, short circuits or abnormal operating conditions help de-energise the unhealthy section of the power system and restrain interference with the remainder of it and thus limit damage to equipment and ensure safety of personnel. They are also used to indicate the type and location of failure so as to assess the effectiveness of the protective schemes.

0.3 The features which the protective relays should possess are:

a) Reliability, that is, to ensure correct action even after long periods of inactivity and also to offer repeated operations under severe conditions;

b) Selectivity, that is, to ensure that only the unhealthy part of the system is disconnected;

c) Sensitivity, that is, detection of short-circuit or abnormal operating conditions;

d) Speed to prevent or minimize damage and risk of instability of rotating conditions; and

e) Stability, that is, the ability to operate only under those conditions that call for its operation and to remain either passive or biased against operation under all other conditions.

0.4 Power relays are inherently directional with respect to the flow of power. They have been employed to protect equipment when abnormal operating conditions occur in a part of a system which is otherwise healthy and the abnormality is not caused by a short circuit or an electrical fault.

0.5 In the preparation of this guide considerable assistance has been derived from several published books and from manufacturers' trade literature. Assistance has also been rendered by State Electricity Boards in collecting actual examples.

0.6 This guide has been prepared mainly to assist protection engineers in the application of power relays. However, it is emphasized that it is not intended to specify the relay to be used or to select any particular protective system. The actual circuit conditions in all probability may be different from those illustrated here. Hence the examples cited should be regarded as mere illustration of one or the other point pertinent to the subject.

0.7 This guide is one of the series of application guides for electrical relays for ac systems. The other guides in this series are:

IS : 3638-1966 Application guide for gas-operated relays

IS : 3842 (Part I)-1967 Application guide for electrical relays for ac systems: Part I Overcurrent relays for feeders and transformers

IS : 3842 (Part II)-1966 Application guide for electrical relays for ac systems: Part II Overcurrent relays for generators and motors

IS : 3842 (Part III)-1966 Application guide for electrical relays for ac systems: Part III Phase unbalance relays including negative phase sequence relays

IS : 3842 (Part IV)-1966 Application guide for electrical relays for ac systems: Part IV Thermal relays

IS : 3842 (Part V)-1968 Application guide for electrical relays for ac systems: Part V Distance protection relays

1. SCOPE

1.1 This guide (Part VI) covers application of power relays for ac systems covered by IS : 3231-1965*.

1.2 This guide does not cover the principles of system design and system protection.

2. TERMINOLOGY

2.0 For the purpose of this guide, the following definitions in addition to those given in IS : 1885 (Part IX)-1966† and IS : 1885 (Part X)-1968‡ shall apply.

*Specification for electrical relays for power system protection.

†Electrotechnical vocabulary: Part IX Electrical relays.

‡Electrotechnical vocabulary: Part X Electrical power system protection.

2.1 Angle of Connection — The phase angle by which unity power factor balanced load current flowing in the tripping direction of relay, leads the voltage applied to relay terminals.

2.2 Angle of Phase Compensation (Maximum Torque Angle) — The angle of phase compensation (of a directional relay) is the phase displacement between the current and voltage measured at the relay terminals, at which the relay gives the maximum torque or force.

NOTE — This term is also referred to as characteristic angle.

2.3 Compensation — Phase shifting of one or more energizing quantities by means of series or parallel connected circuit elements for developing a maximum positive torque in a relay supplied with specified energizing quantities.

3. CHARACTERISTICS

3.1 A power relay measures average power of a circuit. It is intentionally designed to be insensitive to instantaneous magnitude of power lest it may operate or vibrate with network current other than that having unity power factor.

3.1.1 Power relay designed for low setting, below 3 percent, is fast operating and needs auxiliary time lag relay for time adjustment. If setting range exceeds 10 percent, a relay movement can be had with adjustable inverse time power characteristic.

3.2 Under faulted conditions of a network, the voltage may fall to a low value and the power factor of the current would be so low that the power relay would not have a decisive torque. A power relay is, therefore, useful only if there is no electrical fault of the nature of a short circuit. Application of power relays for short-circuit protection requires special considerations and special settings.

3.2.1 The torque in a power relay is considered positive for all phase positions of the operating current from approximately 90° lagging to approximately 90° leading with respect to its maximum torque position. This is fixed by the characteristic angle of the power relay and the angle of connection of the energizing quantities.

3.2.2 The relay torque is zero in the region of a current phase approximately 90° lagging or leading the maximum torque position.

3.2.3 The relay torque is reversed and is considered negative for current phases exceeding 90° lagging and leading the maximum torque position.

3.2.4 Depending on the direction of the flow of power at the relaying point the relay torque will be positive or negative and the relay signal will depend upon the arrangement of contacts.

3.3 Power relay should not be used as a discriminating protection by time grading of two or more relays, which have inverse time-power operating characteristics. Its time characteristic is, however, an asset if transient surges of power are expected while synchronizing.

3.4 The minimum pick-up value of a power relay is constant in watts but the pick-up current value changes according to the power factor. The value is usually specified with respect to the maximum torque position, being the lowest value.

3.5 Power relay can be used as a reactive power relay by choosing suitable energizing quantities and suitable compensation.

4. GENERAL INFORMATION

4.1 Relay Movement — Power relays are constructed employing wattmeter movement. The most common are the induction disc and the cup movements. Single-phase relays have one electrical element while polyphase relays may have two or three electrical elements according to three-phase-three-wire or four-wire circuit connections.

4.1.1 Single-phase power relay is often applied on three-phase balanced system as the abnormal conditions against which the relay provides protection, are also balanced conditions (*see* **5.1**). A single-phase power relay may not always have sufficient torque to permit very low, sensitive setting that may be required. In such a case a polyphase relay which has inherently stronger torque and which permits low, sensitive setting, becomes imperative for use.

4.1.2 A two element or three-phase-three-wire type power relay is applied to balanced three-phase system in preference to a single-phase relay if a strong torque and low sensitive setting is necessary.

4.1.3 A three element or three-phase-four-wire type power relay is applied to an unbalanced or a balanced three-phase system where use of a low setting is necessary.

4.2 Classification of Power Relays — Power relays are classified as overpower, underpower, reverse-power, inverse-power and power regulation relays according to the operating range of settings and their physical arrangement of contact systems.

4.2.1 The overpower and underpower relays look and develop a positive torque in the direction of normal power flow in the circuit at the relaying point.

4.2.2 The reverse power relays look and develop positive torque in opposite direction of normal power flow in the circuit at the relaying point. Their

contact systems are alike but their energizing quantities have different sequence of rotation.

4.2.3 Power regulating relays have a neutral position corresponding to zero torque and have contact systems on either side of neutral position, one of which operates depending upon the sense of the operating torque, that is, whether it is positive or negative.

4.3 The power relays should be energized with voltage and current of the same frequency for proper torque development. The relay to be applied in a given system should have the rated frequency equal to the nominal system frequency; this is most important when the relay is compensated with frequency dependent circuit elements.

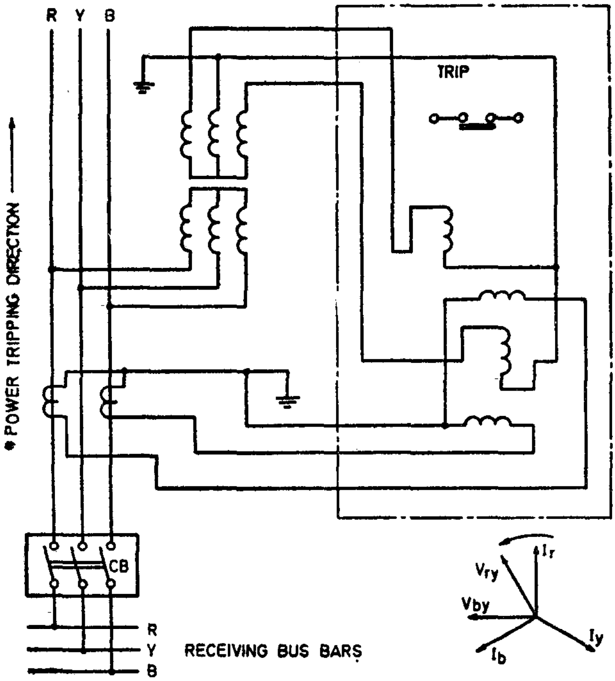

Fig. 1 Reverse Power Protection with Two-Element Three-Phase-Three-Wire Power Relay

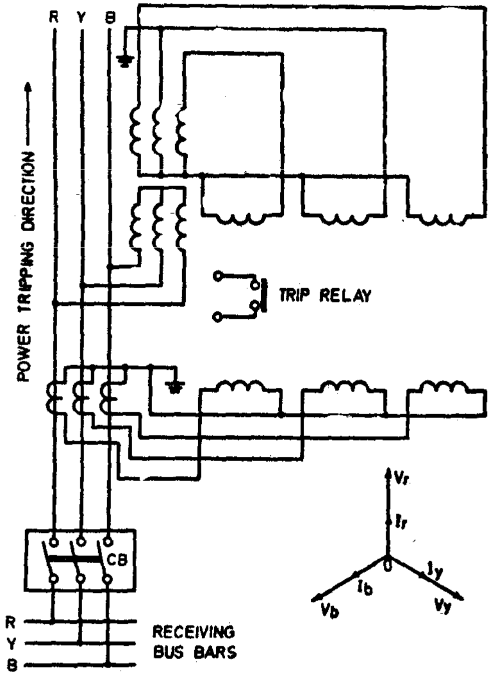

FIG. 2 REVERSE POWER PROTECTION WITH THREE ELEMENT THREE-PHASE-FOUR-WIRE POWER RELAYS

5. APPLICATIONS

5.1 Antimotoring Protection for Generating Set

5.1.1 A prime mover driving a generator is generally required to be shut down in the event of an emergency resulting from serious failures of mechanical type such as failure of thrust bearing, loss of bearing oil pressure, loss of cooling water for bearing oil, etc. If the driven generator is operating in parallel with other generators in an electric system, it is customary in an event of such emergency to shut off input to the prime mover first and allow the generator to idle in the electric system for a short time before the generator is isolated from the electric system by opening its breaker. This is to ensure that the rotating system at synchronous speed does not accelerate, which may if the generator breaker is also immediately opened, and the generator load is thrown off. Further the rotating system shall be quickly isolated from the electrical side as otherwise in a brief time it begins to be driven by the generator now operating

as a motor lightly loaded to the extent of the idling losses which are supplied from the electric system. The condition if prolonged is harmful to the prime mover, though not to the generator, the extent of harm being different according to the type of prime mover as explained in **5.1.1.1** to **5.1.1.4**.

5.1.1.1 *Steam turbine* — The cooling effect of a large steam flow is lost as soon as the emergency stop valves close and hence the idling rotor blades, the casing on the low pressure stages and the exhaust hood begins to overheat. A dangerous temperature may be attained within 30 seconds to a few minutes according to the type of the steam turbine. A condensing turbine would take a few minutes but a back pressure turbine would not take more than 30 seconds to reach dangerous temperature. If vacuum braking is employed on condensing turbines, they run the same risk as back pressure turbines.

5.1.1.2 *Hydraulic turbines* — Reaction and Kaplon type hydraulic turbines are known to suffer from cavitation on loss of water. The heating of blades may occur but is usually not serious as the rotor speeds are not great

5.1.1.3 *Gas turbine* — The turbine itself does not suffer anyway when motoring commences. The motoring power drawn by the generator from the electrical system would be a major loss to a system depending upon the design of the turbine (*see* Table 1). Protection is required to avoid wastage of electrical energy.

5.1.1.4 *Diesel engine* — When motoring commences, any unburnt fuel in the midst of combustion will cause fire and possibly an explosion. No mechanical protection is available to protect against this condition. The motoring load of the diesel engine is also high (*see* Table 1) which results in sizeable loss of energy. Electrical protection for this condition is necessary.

5.1.2 Motoring load generally imposed by the rotating system varies according to the type of the prime mover. It is approximately related with the rating of the generator as shown in Table 1.

5.1.3 Motoring condition can be detected in a steam turbine generator by pressure and steam flow switches. This method is easily applied to non-reheat turbines but for reheat turbines it becomes complicated. Besides, failure of these devices for mechanical trouble is known to be common; hence they do not provide a sufficiently reliable protection. The method is not applicable to other types of prime movers. The electrical method of detection using a power relay is available for application in all cases to which recourse is universally taken.

5.1.4 As motoring load is electrically symmetrical even a single element type reverse power relay having a suitable range of setting will provide reliable electrical protection against motoring of steam turbine. Two and

TABLE 1 MOTORING POWER

(*Clauses* 5.1.1.3, 5.1.1.4 *and* 5.1.2)

TYPE OF PRIME MOVER	MOTORING POWER, PERCENT OF RATED kW	REMARKS
(1)	(2)	(3)
Steam turbine	3	Provided steam cut off is totally complete
Water turbine		
a) Reaction	>2	If blades are set under tail water
	0·2 — 2	If blades are set above tail water
b) Kaplan	<0·2	—
Gas turbine	10 — 50	Dependent on design
Diesel engine	15 — 25	Dependent on number of cylinders and the governor action

three element relays which provide more sensitive range of settings can be applied to antimotoring protection of water turbines. There are no special problems with other type of prime movers, the application to water turbines is occasional, but in the case of application to steam turbine attention is invited to the considerations given in **5.1.5** to **5.1.7**.

5.1.5 At the instant of synchronizing a turbo-generator, a possibility exists of power inrush into the generator from the electric system with which it is synchronized. A reverse power relay would maloperate in such an event. To ensure a successful synchronizing it is customary to restrain the tripping signal of the reverse power relay by a series connected auxiliary contact of emergency stop valve of the turbine. This contact opens when the valve is open and restrains the trip signal given by a maloperating relay. This produces another difficulty, that the auxiliary contact would not certainly close always when the emergency stop valve closes, thus jeopardizing antimotoring protection which is most needed. This is overcome by energizing an auxiliary time delay relay through the trip contact of the reverse power relay such that if the normal tripping signal does not go through, a time delay contact (30 to 45 seconds) of the auxiliary relay would secure tripping of the generator breaker. For non-condensing turbines as well as condensing turbines equipped with vacuum brake system this delay should not exceed 30 seconds. Alternatively, the reverse power relay tripping contact may be connected in series only with an auxiliary ' b ' type contact of the synchronizing switch to render maloperation of the relay ineffective.

5.1.6 A phenomenon encountered in steam turbine is that emergency stop valves do not always close tightly to cut off steam completely. In

practice there is a little leakage of steam. On large reheat turbines there may be as many as 10 valves on the high temperature end. Thus a little leakage through as many valves will be significant. If the total leakage is up to 1 percent of the rated steam flow, the generator would not absorb motoring power from the system but on the contrary it would generate a small forward power. This operation is as dangerous as motoring because the small steam flow is too inadequate to provide cooling effect on the turbine blades. In this case an underpower relay having a low range of settings and permitting a comfortable setting of 0·5 percent rated power of generator should give adequate protection. The measurement of power shall be fairly accurate to permit such low setting on underpower relays having fixed compensation. The phase angle error of the instrument transformers must be controlled while selecting equipment. The algebraic sum of the phase angle errors of the current and potential transformers shall be less than 30 minutes. Alternatively an underpower relay having adjustable compensation shall be selected to permit site adjustment for correct measurement of power through the instrument transformers.

5.1.7 Motoring of water turbine generators is not as harmful as of steam turbo-generators. Hydraulic turbines operate at relatively low speeds and hence they can be designed to withstand larger overspeed. It is customary in attended stations to trip the generator breaker along with the water shut off valve. Reliance is then placed on the operator taking adequate manual action for shutting the machine. In unattended stations, however, protection against motoring is provided by means of a sensitive power relay connected to trip the generator breaker subsequent to the closing of turbing shut off valve.

NOTE — For faults on the electrical side in the generator, the generator breaker is tripped simultaneously with the input valve of the prime mover. Protection for this condition is given in IS : 3842 (Part VII)-1972* and IS : 3842 (Part VIII)†.

5.2 Generator Protection

5.2.1 Synchronous generators whose neutral end connections are not accessible, cannot be protected with conventional differential protection and earth-fault protection. Such a generator can be protected by means of an inverse power relay, that is, a reverse power relay energized with negative sequence components of voltage and current from the terminals of the generator. A negative sequence filter is employed for feeding negative sequence quantities to the relay.

5.2.2 The relay will protect a generator against short circuits between phases away from the neutral, inter-turn faults of 20 to 100 percent of

*Application guide for electrical relays for ac systems: Part VII Frequency relays.

†Application guide for electrical relays for ac systems: Part VIII Voltage relays (*under preparation*).

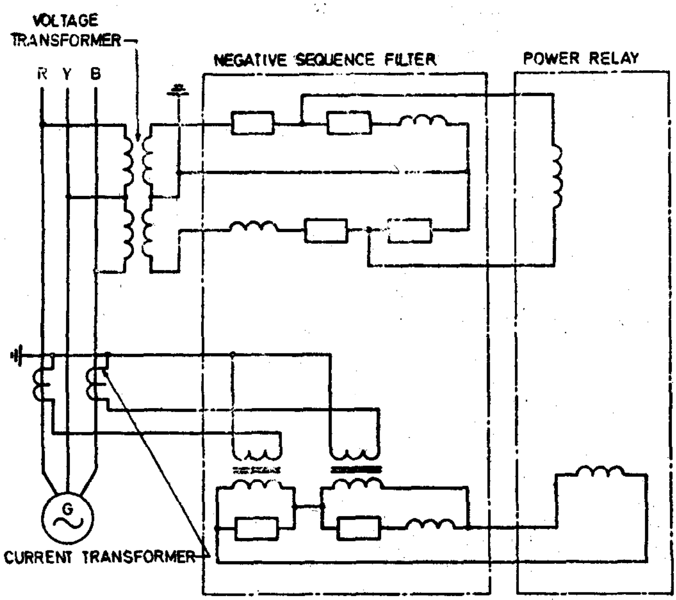

FIG. 3 PROTECTION OF AN ALTERNATOR WITH INACCESSIBLE NEUTRAL

phase winding and asymmetrical earth faults, double earth faults such as in the generator phase or on transmission line. The relay may not give a sensitive protection for all types of faults.

5.3 Synchronous Motor Protection

5.3.1 If power supply to a synchronous motor fails, the motor is required to be immediately disconnected from the supply, otherwise there is the risk of supply reappearing at the motor terminals out of synchronism with the motor internal voltage.

5.3.2 A single element under power relay preferably with quadrature connection and a setting below the light running load of the motor can be employed to ensure isolation of the motor from the power supply.

5.3.3 Underpower relays should be used when there is no possibility of other electrical load being connected to the busbars when the supply fails. If there is always some electrical load connected to the busbars, a reverse power relay is better than an underpower relay as this will be more stable under small power reversals due to the loading conditions. In these applications, it is essential to incorporate a slight time delay to overcome momentary power reversals due to system faults, etc.

5.3.4 Underpower relays can be applied only if power reversals do not occur under normal operating conditions. Otherwise, underfrequency relays will have to be used [*see* IS : 3842 (Part VII) 1972*].

5.4 Switching of Capacitors for Power Factor Control

5.4.1 Power relay is used for automatic switching of static capacitor banks on a line feeding industrial loads of low power factor. The relay is of single element type, connected in quadrature connection with a compensation such that the torque on the moving element is zero when the power factor of the relayed circuit is unity. Any change from unity power factor will produce relay torque in the load or lag sense according to the circuit power factor.

5.4.2 A power regulating type relay having a neutral position for its moving contact and fixed contact systems on either side is generally employed in this application. The fixed contacts have independently adjustable physical positions calibrated with respect to a scale and this affords fine adjustment of setting. The current coil is tapped for coarse adjustment of setting.

5.4.3 The three-phase kVA equal to 100 percent setting of the relay is calculated from the following expression:

$$\frac{\sqrt{3} \times \text{rated relay volts} \times \text{VT ratio} \times \text{rated relay amps} \times \text{CT ratio}}{1\,000}$$

The actual relay setting to be adopted for switching capacitor bank shall always be smaller than the three-phase kVA rating of the capacitor bank switched in the one step. The difference in the relay setting kVA and the capacitor bank step kVA switched, should not be excessive lest hunting may occur. The setting kVA should be between 80 to 85 percent of the capacitor kVA switched for satisfactory operation.

5.4.4 An illustration of a single step capacitor bank switching control is shown in Fig. 4. If the hand or auto switch is on hand position, the capacitor bank remains switched on the line as long as the supply is present. The relay control comes into action when the hand or auto switch is turned to auto position. When the load draws a lagging power factor current, the lag contact of the power relay closes, switches the capacitor bank on the line and the switching contactor seals in through its auxiliary contact 'C'. If the load decreases the power factor improves to unity and the relay drops to its neutral position. With further decrease in the load, the circuit draws leading current when the lead contact of the power relay closes. It shorts the holding coil of the switching contactor. The contactor drops switching off the capacitor bank.

5.4.5 The capacitor switching can be done part by part by multistep switching control illustrated in Fig. 5. The power relay is equipped with a

*Application guide for electrical relays for ac systems: Part VII Frequency relays.

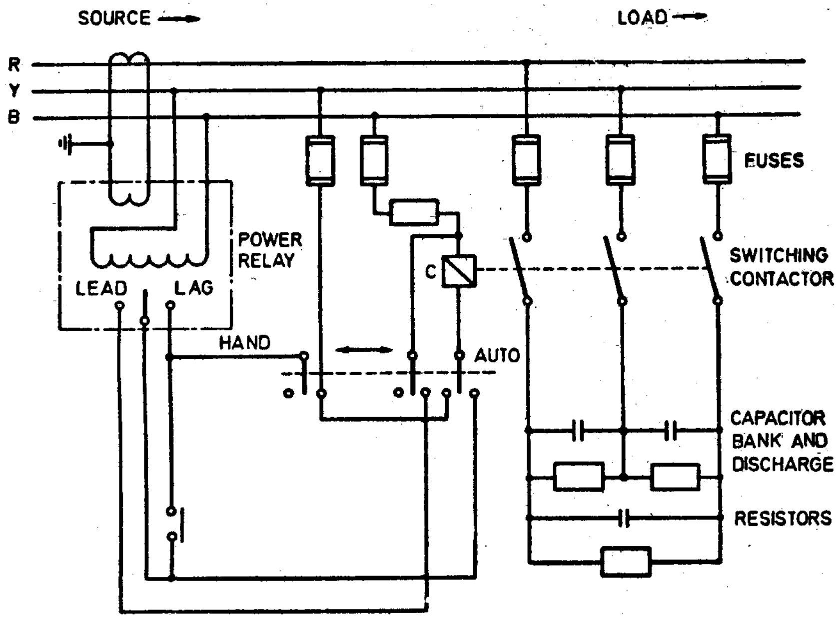

Fig. 4 Three-Phase Capacitor Switching Single Step Control

high torque reversible synchronous motor which drives cam operated mercury contacts in the stepping control. In the illustration the switching contactors and stepped capacitor banks are not shown. Only the holding coils of the switching contactors are shown for simplicity. The *NO* mercury contacts are individually wired in series with the holding coils of the contactors. A *NC* mercury contact is wired in series with a resulting relay *R* for initiating the step control. When the supply is on, the resetting relay *R* picks up and prepares the motor circuit and the circuits of the holding coils. When the load draws lagging current, the lag contact of the relay makes, the motor is energized and turns to throw the circuit of the resetting relay on its holding contact and to close the circuit of the first holding coil of the switching contactor. If the lagging current in the load is sufficiently reduced in conformity with the setting of the relay, the relay will drop to neutral position and the motor is de-energized. If not, the motor will turn further bringing additional capacitor banks on the line until the relay drops to its neutral position and the lagging current on the load is reduced as determined by the relay setting. Thereafter if the load decreases, the load current leads due to excess capacitors on the line, the lead contact of the relay closes and the motor is energized to drive the cam shaft in reverse direction. The mercury contacts open one after another and the switching contactors are released,

until the relay drops again to its neutral position. If the power supply were to fail momentarily any time the capacitors are switched on line, on reappearance of the supply, the capacitors on line would be in excess of the load which may have itself dropped out. Dangerous overvoltage may occur. To safeguard against this, the resetting relay would drop out on failure of supply and switch out all the holding coils. When the supply reappears, the resetting relay will not pick up, but the motor will turn to return the cam shaft to its initial position. The resetting relay will then pick up and establish normalcy. The setting of the power relay for multistep switching should be 80 to 85 percent of the step value of the capacitor kVA switched each time.

5.5 Switching Off of Transmission Lines for Reducing Excessive Leading Vars — Under light load conditions, rise in voltage may take place at various points in the system. In this case it may be required to give an alarm or trip out some of the feeders at selected points by using a varmetric relay along with an overvoltage or an underpower relay. On double circuit lines, one of the circuits may be tripped out. Varmetric relays are connected to produce maximum torque when the current leads the voltage by 90°.

5.6 Power Interchange in Systems — Power may be interchanged between two systems belonging to different ownerships in which case restraints are necessary on the interchange for commercial or technical reasons. Power relays are often used to realise these restraints solely by themselves or in combination with frequency relays [*see* IS : 3842 (Part VII)-1972*].

5.6.1 *Major-Minor Interconnection*

5.6.1.1 Frequently encountered interconnection is one between a major utility power system and a minor industrial power system. The industrial power system (IPS) would normally generate its own power either:

a) to meet its most essential load, power for non-essential loads being drawn from utility power system (UPS), or

b) to meet all its load with normally an interconnection being maintained with the UPS for alternate firming supply, or

c) as incidental to production of low pressure steam for industrial process, reliance being mainly placed on power drawn from the UPS.

5.6.1.2 In some cases overpower relays looking towards the utility power system bus may be used instead of reverse power relays if the industrial system is designed to feed back certain amount of power to the grid in case of emergency. For such applications, it is essential to incorporate a slight time delay to overcome momentary power reversals and to ensure co-ordinations with back-up protection on the system.

---

*Application guide for electrical relays for ac systems: Part VII Frequency relays.

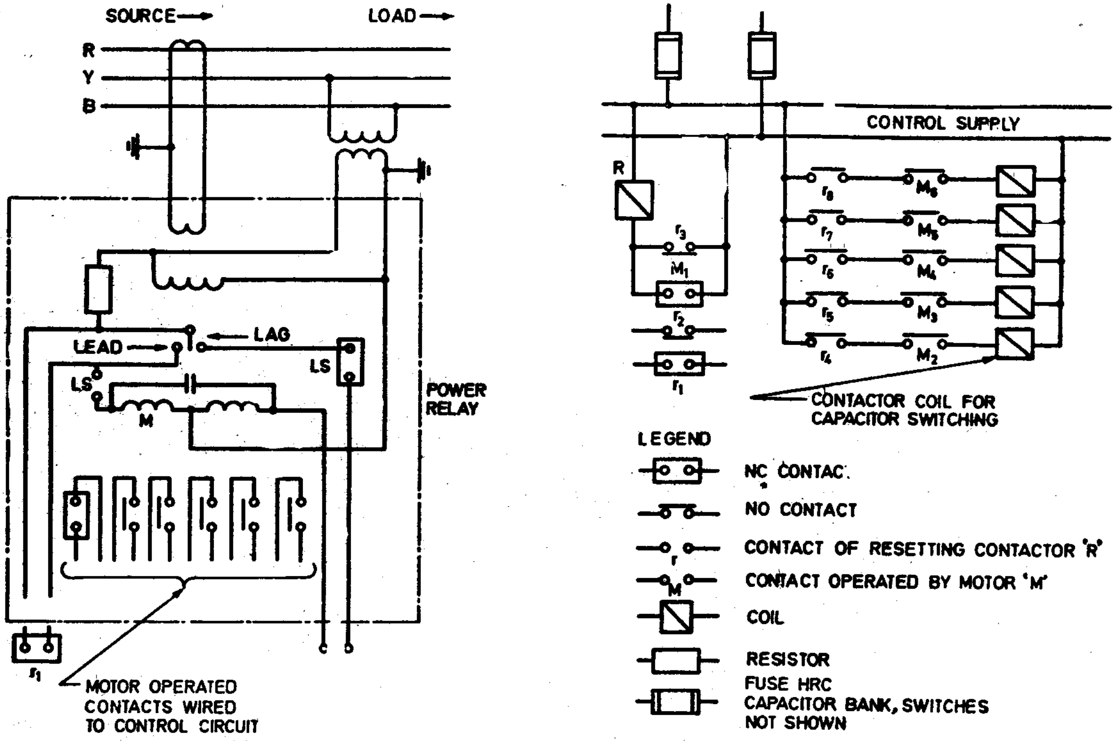

Fig. 5 Multistep Capacitor Switching

5.6.1.3 A typical system is illustrated in Fig. 6. If the supply fails at the utility bus or the utility circuit-breaker trips on line fault, the industrial power system would attempt to feed the tapped load. It may not have sufficient generating capacity even to meet all the load on its own bus. The industrial power system can be saved from instability by the use of reverse power relay which is connected to operate on reversal of power flow in the direction of the utility and arranged to trip the utility feeder circuit-breaker at the industry bus together with the circuit breakers of the non-essential load supplied from the industry power bus. The industries' generators would then continue to feed only the essential load within the generating capacity. To prevent maloperations during synchronizing and system faults, a time delay feature should be incorporated.

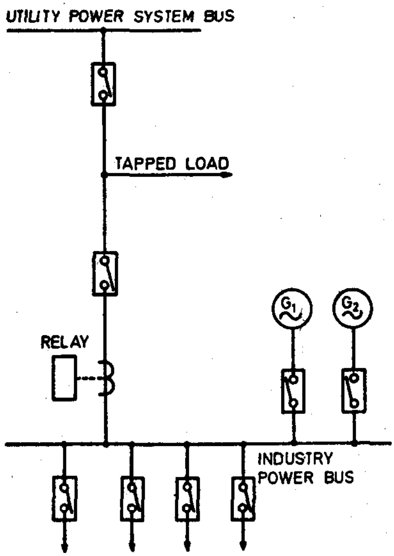

FIG. 6 INTERCONNECTION OF MAJOR AND MINOR POWER SYSTEM

5.6.2 *Major-Major Interconnection* — The power relay finds application as an auxiliary logic aid to underfrequency relay for system splitting or severance of interconnection [*see* IS : 3842 (Part VII)-1972*].

5.6.3 *Tariff Control* — In interconnected power networks, power exchange may take place on restricted quota basis, that is, one utility may supply a maximum of agreed power to the other utility. If power drawn by the second utility exceeds the agreed quota, control can be effected by means

*Application guide for electrical relays for ac systems : Part VII Frequency relays.

of an overpower relay looking in the appropriate direction and connected to an audible alarm. The relays can be connected at both transmitting and receiving ends of lines to sound alarms. Power interchange is then controlled manually. Tripping can be arranged by auxiliary time-delay relay which allows adequate time for the receiving party to reduce off-take. The details of application depend on commercial agreement and relationship rather than technical factors.

5.6.4 *Control of Vars* — In interconnected power networks, normally each utility should generate its own lagging vars and exchange of vars on tie lines should be limited. Varmetric relays may be used to give an alarm in case excessive vars flow on the tie lines. This will ensure optimum use of lines for transferring power from one utility to another.